# Biological Evaluation

# of the Gypsy Moth Populations

# on the Monongahela National Forest, West Virginia

Prepared by

Richard M. Turcotte, Entomologist
Forest Health Protection

And

Ann Steketee, GIS Specialist
Information Management and Analysis

USDA Forest Service
State and Private Forestry
180 Canfield Street
Morgantown, WV 26505

December 2002 (NA-03-01)

## ABSTRACT

In the fall of 2002, personnel from USDA Forest Service, Northeastern Area, Forest Health Protection, Morgantown Field Office conducted gypsy moth egg mass surveys on the Monongahela National Forest (MNF). The purpose of these surveys was to estimate gypsy moth population densities through fall egg mass counts, and to assess the need for treatment in 2003. Predicted populations densities were estimated to be sufficient to cause moderate to heavy defoliation on 5,216 acres in 2003. Treatment to prevent defoliation is recommended in those areas where the predicted level of defoliation has the potential to cause a reduction in tree growth, reproduction (flowering and seed production), and an increase in tree mortality, all of which can conflict with existing forest management objectives.

## INTRODUCTION

Aerial surveys performed by the Forest Service and the State of West Virginia identified 27,866 acres of oak forest defoliated by the gypsy moth this year on the Monongahela National Forest. This is a large decline from the 46,039 and 42,515 acres defoliated in 2001 and 2000, respectively. Many of the areas defoliated this year also experienced defoliation in 2001 and 2000. This defoliation, in combination with the dry conditions this summer, might result in a reduction in tree growth, reproduction (flowering and seed production), and an increase tree mortality, all of which can conflict with existing forest management objectives.

The gypsy moth, *Lymantria dispar* (Linneaus) is a non-native defoliator of forest, shade and ornamental trees throughout the Northeastern United States. Since its intentional importation and accidental release in eastern Massachusetts in 1869, the gypsy moth has steadily expanded its range. Despite many attempts to halt its spread westward from the northeastern United States, West Virginia experienced its first gypsy moth defoliation in 1985. Since that time, the gypsy moth has defoliated nearly 2.1 million acres in the state.

The gypsy moth produces one generation per year. Larvae begin hatching from egg masses in late April and early May when tree buds begin to open. At this time, larvae go through an obligatory dispersal period where they leave the vicinity of the egg, moving upward and spinning a thread of silk as they go (Leonard 1981). Eventually the wind catches the larvae and disperses them. Airborne larvae are carried and deposited some distance downwind from the source with the following results: 1) larvae will land on or crawl onto acceptable host plants and begin feeding; 2) larvae will land on either acceptable or unacceptable and re-disperse; 3) larvae will be deposited into areas unacceptable for survival and re-dispersal where they will die (Mason and McManus 1981). The larvae feed for two to three months completing their development by late June and early July and seek sheltered areas in which to pupate. The gypsy moth pupal period last from 10 days to two weeks. The females, which cannot fly, crawl a short distance from where they emerged and emit a pheromone scent to attract males. After mating, the female lays a single egg mass that contains from 75 to 1,000 eggs, which she covers with hairs from her abdomen giving it a fuzzy brown texture and color. The egg masses over winter and hatch the following spring.

The number of host trees and shrubs fed on by the gypsy moth exceeds 300 species, with species of oaks (*Quercus* spp.) ranked among the most favored (Leonard 1981). Gypsy moth is an outbreak species whose populations can remain at low levels for several years, then undergo large population increases in a matter of one or two years. After populations have increased to an outbreak density they can remain high for one to five years, outbreaks decline suddenly to low densities where it is difficult to find any life stage (Liebhold et al. 2000). The main effects of gypsy moth feeding on individual trees involves the depletion of root carbohydrate food resources leading to a reduction in growth, reproduction, and increased vulnerability to secondary agents of mortality. Heavy defoliation forces re-foliation, which uses carbohydrate reserves in trees and can increase their vulnerability to drought and to other insects and diseases. This defoliation and subsequent tree mortality can alter wildlife habitats, change water quality and temperature, increase forest floor temperatures and light levels and reduces aesthetic, recreational, and property values of forests and urban environments.

## OBJECTIVES

The objectives of this biological evaluation were to: 1) accurately assess current gypsy moth population densities within susceptible forest types on the Monongahela National Forest; 2) determine the likelihood of unacceptable impacts on MNF forest resources occurring in the next growing season; 3) develop treatment alternatives and recommendations to suppress gypsy moth outbreaks likely to cause unacceptable impacts.

## METHODS

The guidelines used to evaluate the risk of defoliation include: 1) current defoliation level as defined by aerial surveys; 2) previous defoliation events; 3) number of egg masses/acre; 4) size and condition of the egg masses; 5) presence of disease and parasites; 6) availability of preferred food (mainly oaks); 7) risk of larval blow-in following egg hatch.

Based on a decision by the MNF, only seven of the fourteen 2002 proposed spray blocks (Acciavatti and Steketee 2001) and the defoliated area north of Lake Sherwood were surveyed this year. Defoliation predictions for 2003 within survey areas were based on three egg mass density thresholds relating to ranges in predicted percent defoliation: 1) 250-egg masses/acre "light" (1-30 percent defoliation); 2) 500-egg masses/acre "moderate" (31-60 percent); 3) 1000-egg masses/acre "heavy" (61-100 percent).

The number of survey plots within each unit was based on the sequential sampling plan developed by Fleisher et al. 1992. Predefined proposed 2002 spray blocks and areas mapped as defoliated during the 2002 aerial survey were overlaid by a one-kilometer grid using GIS. A minimum of four sample points were randomly generated within each unit with additional survey sites being chosen at random. Ecological land type data provided by the MNF were used to insure that sample points were located in susceptible host type (mainly oaks). A total of 93 sample points were established throughout the forest.

During this survey, 1/40th acre (18.6-ft radius) plots were used to estimate egg mass densities within susceptible forest type areas. At each sample point, a 1/40th acre fixed radius plot was established and the percent new egg masses was determined by inspection and visual count. An inspection of all egg masses within reach helped estimate the portion of new to old egg masses at each plot. Egg masses visual counts consisted of a tally of all egg masses observed on the overstory trees, understory vegetation, ground litter and duff. The total number of egg masses observed for each plot was summed and multiplied by the ratio of new egg masses to old egg masses (Liebhold et al. 1993). This calculated new egg mass density was compared to the decision chart for management thresholds (Table 1). If the cumulative egg mass count was above or below the threshold the sampling was stopped, if it was in the "continue sampling" range then another random sample was taken. This method was continued until a decision to stop was reached or until the maximum number of samples was reached. Ten samples was the maximum for this evaluation. Table 2 provides the equations used to generate Table 1.

Table 1-Sequential sampling decision charts for three management thresholds in continuously forest eastern hardwoods (Fleisher et al 1992).

| Threshold (Egg masses/acre) | Sample Number (1/40 acre) | Stop Sampling (below threshold) | Continue Sampling | Stop Sampling (above threshold) |
|---|---|---|---|---|
| | | | Cumulative Egg Mass Count | |
| 250 | 4 | 0-6 | 7-42 | >42 |
| | 5 | 0-12 | 13-48 | >48 |
| | 6 | 0-18 | 19-54 | >54 |
| | 7 | 0-24 | 25-60 | >60 |
| | 8 | 0-30 | 31-66 | >66 |
| | 9 | 0-36 | 37-73 | >73 |
| 500 | 4 | 0-15 | 16-81 | >81 |
| | 5 | 0-27 | 28-94 | >94 |
| | 6 | 0-39 | 40-106 | >106 |
| | 7 | 0-52 | 53-118 | >118 |
| | 8 | 0-64 | 65-130 | >130 |
| | 9 | 0-76 | 77-143 | >143 |
| 1000 | 4 | 0-18 | 19-178 | >178 |
| | 5 | 0-43 | 44-202 | >202 |
| | 6 | 0-67 | 68-227 | >227 |
| | 7 | 0-92 | 93-252 | >252 |
| | 8 | 0-116 | 117-276 | >276 |
| | 9 | 0-141 | 142-301 | >301 |

Table 2. – Equations used to generate sequential sampling plans for 1/40th acre fixed radius plot samples in continuously forested habitat (Fleisher et al 1992).

| Threshold (egg masses/acre) | Decision Stop Line[a] |
|---|---|
| 250 | $Y = 6.095x \pm 17.722$ |
| 500 | $Y = 12.178x \pm 32.706$ |
| 1000 | $Y = 24.580x \pm 79.461$ |

[a] Decision stop line form $y=mx \pm b$, where y = cumulative sum required to stop sampling, m is the slope, x is the sample number and b is the intercept. The positive value of the intercept gives the upper stop line and the negative value gives the lower stop line.

## RESULTS

The seven survey areas are represented in Figures 1-8 and the gypsy moth population densities in each area is summarized in Tables 3-9. Overall, average egg mass densities ranged from 0-10,220-egg masses/acre. Three of the survey areas, (Lake Sherwood, North Fork Lookout and Big Mountain) encompassing 5,216 acres contain egg mass densities sufficient to predict moderate (30-60%) to heavy (>60%) defoliation, based on a threshold of 500(+) egg masses per acre. Unless significant blow-in of gypsy moth caterpillars occurs in the spring, the remaining survey areas are unlikely to be defoliated in 2003.

## DISCUSSION

The greatest potential for heavy defoliation in 2003 exists within those survey areas where the egg mass counts exceed the 1,000-egg masses/acre threshold. Defoliation of this intensity can lead to permanent tree damage (crown decline, dieback and mortality). The greatest potential for moderate defoliation in 2003 exists within those areas where the egg mass counts are between 500–1,000 egg masses/acre. Defoliation at these thresholds creates nuisance larval densities and light to moderate defoliation that adversely affects recreation view-sheds, values and uses. Survey plots with low egg mass count of 250 egg masses/acre or less are likely to have "light" defoliation because innocuous gypsy moth populations are present.

Predicting the extent of impact on individual trees as a result of two consecutive in years is difficult, however, in general, trees that are "heavily" defoliated, (in excess of 50-60 percent) normally refoliate the same growing season. Such events cause the trees to expend carbohydrate reserves to refoliate, and consequently cause the trees' health to deteriorate. Depending on the condition of the trees at the time of defoliation, reduced growth, mast abortion (Gottschalk 1989), branch dieback or in some cases tree mortality, has been observed following a single year of heavy defoliation. Should subsequent defoliation occur in following years as it has for many of the survey areas, the impact is compounded.

Trees that receive light-moderate defoliation (< 60 percent) are not likely to refoliate and expend food resources. Therefore, no significant impact on tree health is likely.

A large portion of the current gypsy moth infestation north of Lake Sherwood lies in the leading edge of the generally infested area along the southward expansion of gypsy moth. It is under these circumstances that increased risk from the expanding outbreaks can most impact the forest by increasing tree mortality, especially in the forest habitats composed primarily of oaks, where stands have been defoliated during one or more of the previous years.

The natural control factors operating in the survey areas were not quantitatively surveyed, but observations indicate that the size of new egg masses was moderate to large with an almost constant presence of *Ooencyrtus kuvanae,* a parasitic wasp specific to gypsy moth eggs. Several larval cadavers were collected during the surveys and were found to be harboring resting spores of the gypsy moth fungus, *Entomophaga maimaiga*. This fungus is known to be present wherever gypsy moth is distributed in West Virginia, and was considered to have influenced the

successful reduction of those gypsy moth infestations on the MNF sprayed in 2001 as well as those unsprayed infestations predicted to be defoliated in 2002. It is likely this fungus could adversely influence gypsy moth infestations on the MNF especially if there is wet spring weather. The gypsy moth nucleopolyhedral virus was also present in dead larvae collected, but this pathogen operates at high larval density and does not kill as quickly as the fungus so its effects are usually masked by the presence of the fungus.

## GYPSY MOTH MANAGEMENT OPTIONS

For 2003, three management options have been evaluated based on decisions by the MNF for managing gypsy moth populations. The intervention option is offered based upon the following two treatment objectives: 1) protect host tree foliage to prevent mast failure and tree mortality; and 2) reduce gypsy moth population below the treatment threshold. Each option is discussed below.

## NO ACTION OPTION

It is possible that gypsy moth populations could collapse due to the presence of the gypsy moth nucleopolyhedrosis virus (NPV) or the gypsy moth fungus, *Entomophaga maimaiga.* Where defoliating gypsy moth populations are greater than 500 egg masses/acre viral epizootics generally manifest themselves only after significant tree defoliation has already occurred. Gypsy moth populations will usually peak in two-three years once they reach defoliating levels and then collapse as a result of NPV or fungal activity. Residual populations following such a collapse will likely remain at low densities for three-six years before rebuilding to defoliating levels. Although it is difficult to accurately assess the sequence of such events, it is unlikely that a collapse will occur since these areas are in the first or second year of infestation and there is an abundance of large egg masses.

Should this option be selected, it is likely that defoliation will occur and population densities will increase in newly infested stands and expand to currently uninfested areas.

## MICROBIAL INSECTICIDE OPTIONS

The second option is to use a microbial insecticide to manage gypsy moth populations. The only biological insecticide currently registered and commercially available for gypsy moth control is the microbial insecticide, *Bacillus thuringiensis* variety *kurstaki (B.t.k).* This microbial insecticide is available through two manufacturers containing both the spore and crystal as the entomopathogenic ingredients (Reardon et al. 1994) and has been used extensively in suppression projects throughout the U.S. in both forested and residential areas. *B.t.k.* is a bacterium that acts specifically against lepidopterous larvae as a stomach poison and therefore must be ingested. The major mode of action is by mid-gut paralysis, which occurs soon after feeding. This results in a cessation of feeding, and death by starvation. *B.t.k.* has been shown to impact other non-target caterpillars that are exposed to the treatment and are actively feeding. *B.t.k.* is persistent on foliage for about 7-10 days.

*B.t.k* is not target specific and may reduce the populations of non-target organisms either as a consequence of direct toxicity or indirectly, by reducing food supplies. Several factors must be taken into account when using B.t.k such as: 1) the potential for non-target extirpation in the proposed spray area; 2) the life stage present and any deferential susceptibility to *B.t.k* that may exist between species of non-target organisms; 3) the size and uniqueness of the area beginning proposed for treatment. Since much of this site-specific data regarding non-target organisms may not be known for many areas the potential benefits must be weighed against any potential impacts to non-targets.

*B.t.k.* formulations are available as a flowable concentrate. The normal application rates range from 24-36 billion international units (BIUs) per acre in a single or double application. *B.t.k.* can be applied either undiluted or mixed with water for a total volume of ½-1 gallon per acre. With proper application, foliage protection and some degree of population reduction can be expected with one application and with two applications both foliage protection and a greater degree of population reduction are likely. Because *B.t.k.* is a biological insecticide, the degree of population reduction varies and may depend on, at least in part, the selected application rate, relative health of the population (building vs. declining), population densities, weather (rain and temperature), the feeding activity of the larvae following treatment, and the actual potency of the product.

A second microbial insecticide that is registered and available in limited quantities is the formulated nucleopolyhedrosis virus called Gypchek® (U.S. Forest Service, USDA, Washington, DC). This product is not available commercially but is produced in limited quantities by a cooperative effort of the USDA Forest Service and the Animal Plant Health Inspection Service (APHIS). The active ingredient in Gypchek formulations has a very narrow host range (lymantriids) and occurs naturally in gypsy moth populations. Normally the virus reaches epizootic proportions when gypsy moth populations reach high densities as a result of increased transmission within and between gypsy moth generations. The application of Gypchek to gypsy moth populations simply expedites this process by increasing the exposure of the virus at an earlier stage. Healthy, feeding gypsy moth caterpillars become infected by ingesting contaminated foliage and soon stop feeding and die.

The efficacy of Gypchek treatments to reduce gypsy moth populations has been quite variable. Because of the short period of viral activity on foliage (3-5 days) as well as other biological factors such as feeding activity and weather conditions, it has been difficult at best to project treatment efficacy. Most often foliage protection can be achieved but significant reductions in gypsy moth densities do not always occur. Should inadequate population reduction occur, areas would need to be treated again the following year. The normal application rate of Gypchek is $4x10^{11}$ occlusion bodies (OB's) per acre applied once.

With the previously described options in mind, the following alternatives are offered.

Alternative 1. -No action

Alternative 2 -One aerial application of *B.t.k.* at the rate of 36 BIUs in a total mix of ¾ gallons/acre.

Alternative 3 -Two aerial application of *B.t.k.*, as in alternative 2, applied 4-7 days apart.

Alternative 4 -One aerial application of Gypchek at an application rate of $4x10^{11}$ occlusion bodies (OB's)/acre.

Alternative 5 -Two aerial applications of Gypchek as in alternative 4, applied at $2x10^{11}$ occlusion bodies (OB's)/acre applied in two applications, 3-5 days apart.

## RECOMMENDATIONS

It is recommended the MNF decide in favor of alternative two (one aerial application of *B.t.k.*) in the Lake Sherwood area covering 4,400 acres (Figure 8). National Forest resource values, such as recreation, timber, and wildlife would be protected by the suppression of potentially damaging gypsy moth populations where these values are at the greatest risk. This decision would prevent additional unacceptable damage to forest resource values and uses caused by defoliation likely during 2003, especially in areas defoliated in 2002 and 2001.

For the proposed spray blocks (where gypsy moth egg masses exceed the 1,000 egg masses/acre threshold) *B.t.k* would be expected to prevent moderate to heavy defoliation that results in tree permanent tree damage or mortality. For those blocks with gypsy moth egg mass densities that are above the 500 egg masses/acre threshold treatment would be expected to prevent larval nuisance and light to moderate defoliation that adversely affects recreation view-sheds, values and uses.

Alternative 2 is recommended over the other alternatives based on the following considerations.

1) A double application of *B.t.k.* on all 4,400 acres would likely to provide foliage protection and a population reduction but this alternative is also less economical and logistically more complicated than the recommended alternative.

2) A single and/or double application of Gypchek is likely to provide foliage protection and a population reduction. Gypchek has a shorter activity period (3-5 days) then the recommended single *B.t.k* (7-10 days) alternative and is also less economical due to the cost of the carrier.

## REFERENCES


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Table 3—Gypsy moth egg mass survey results for the Monongahela National Forest (Fore Knobs Cable), September 10, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 1 | 100 | 3 | 132 |
| 2 | 84 | 4 | 224 |

**Egg Mass Threshold -1000** **Cum. EM Count = 13.5**
**Em/Acre Range = 84-224** **Em/Acre Average = 135**
**Comments: EM*, NPV$^{+}$, Egg Parasites$^{\#}$ Present**

Table 4—Gypsy moth egg mass survey results for the Monongahela National Forest (Redman Run), September 21, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 5 | 0 | 8 | 968 |
| 6 | 412 | 9 | 528 |
| 7 | 260 | | |

**Egg Mass Threshold -1000** **Cum. EM Count = 54**
**Em/Acre Range = 0-968** **Em/Acre Average = 433**
**Comments: NPV$^{+}$, Egg Parasites$^{\#}$ Present**

Table 5—Gypsy moth egg mass survey results for the Monongahela National Forest (Forest Trail 502), September 23, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 10 | 0 | 12 | 0 |
| 11 | 0 | 13 | 0 |

**Egg Mass Threshold -250** **Cum. EM Count = 0**
**Em/Acre Range = 0** **Em/Acre Average = 0**
**Comments: none**

Table 6—Gypsy moth egg mass survey results for the Monongahela National Forest (North Fork Lookout), October 3, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 14 | 10220 | 16 | 3280 |
| 15 | 6520 | 17 | 3840 |

**Egg Mass Threshold -1000** **Cum. EM Count = 596.5**
**Em/Acre Range = 3280-10220** **Em/Acre Average = 5965**
**Comments: Egg Parasites[#] Present**

Table 7—Gypsy moth egg mass survey results for the Monongahela National Forest (Pretty Ridge), October 3, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 18 | 0 | 20 | 0 |
| 19 | 72 | 21 | 0 |

**Egg Mass Threshold -1000** **Cum. EM Count = 1.8**
**Em/Acre Range = 0-72** **Em/Acre Average = 18**
**Comments: EM*, NPV[+], Egg Parasites[#] Present**

Table 8—Gypsy moth egg mass survey results for the Monongahela National Forest (Big Mountain), October 4, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 22 | 436 | 26 | 1016 |
| 23 | 2116 | 27 | 1548 |
| 24 | 1708 | 28 | 1240 |
| 25 | 1888 | | |

**Egg Mass Threshold -1000** **Cum. EM Count = 249**
**Em/Acre Range = 436-2116** **Em/Acre Average = 1421**
**Comments: EM*, Egg Parasites[#] Present**

Table 9—Gypsy moth egg mass survey results for the Monongahela National Forest (Lake Sherwood, including Meadow Creek Mountain), October 21-November 26, 2002.

| Plot Number | Number Egg masses/Acre | Plot Number | Number Egg masses/Acre |
|---|---|---|---|
| 29 | 0 | 62 | 388 |
| 30 | 0 | 63 | 280 |
| 31 | 0 | 64 | 280 |
| 32 | 0 | 65 | 1080 |
| 33 | 1872 | 66 | 0 |
| 34 | 3336 | 67 | 0 |
| 35 | 1032 | 68 | 0 |
| 36 | 8888 | 69 | 0 |
| 37 | 696 | 70 | 0 |
| 38 | 412 | 71 | 0 |
| 39 | 480 | 72 | 0 |
| 40 | 220 | 73 | 1988 |
| 41 | 1040 | 74 | 1252 |
| 42 | 0 | 75 | 3724 |
| 43 | 820 | 76 | 384 |
| 44 | 356 | 77 | 852 |
| 45 | 868 | 78 | 384 |
| 46 | 792 | 79 | 320 |
| 47 | 0 | 80 | 0 |
| 48 | 0 | 81 | 352 |
| 49 | 0 | 82 | 680 |
| 50 | 296 | 83 | 0 |
| 51 | 0 | 84 | 0 |
| 52 | 316 | 85 | 0 |
| 53 | 2912 | 86 | 0 |
| 54 | 636 | 87 | 280 |
| 55 | 124 | 88 | 428 |
| 56 | 600 | 89 | 140 |
| 57 | 236 | 90 | 3280 |
| 58 | 640 | 91 | 264 |
| 59 | 272 | 92 | 1440 |
| 60 | 640 | 93 | 0 |
| 61 | 768 | | |

**Egg Mass Threshold –250-500** **Cum. EM Count =Multiple cells**
**Em/Acre Range = 0 – 8888** **Em/Acre Average = 708**
**Comments: EM*, NPV$^{+}$ Present**

***EM** - Cadavers with *Entomophaga maimaiga* present
$^{+}$ **NPV** - Cadavers with nucleopolyhedrosis virus present
$^{\#}$ **Egg Parasites –** Presence of *Ooencyrtus kuvanae* parasitic wasps observed

Figure 1. Monongahela National Forest 2002 proposed treatment areas, and 2003 egg mass counts-Lake Sherwood.

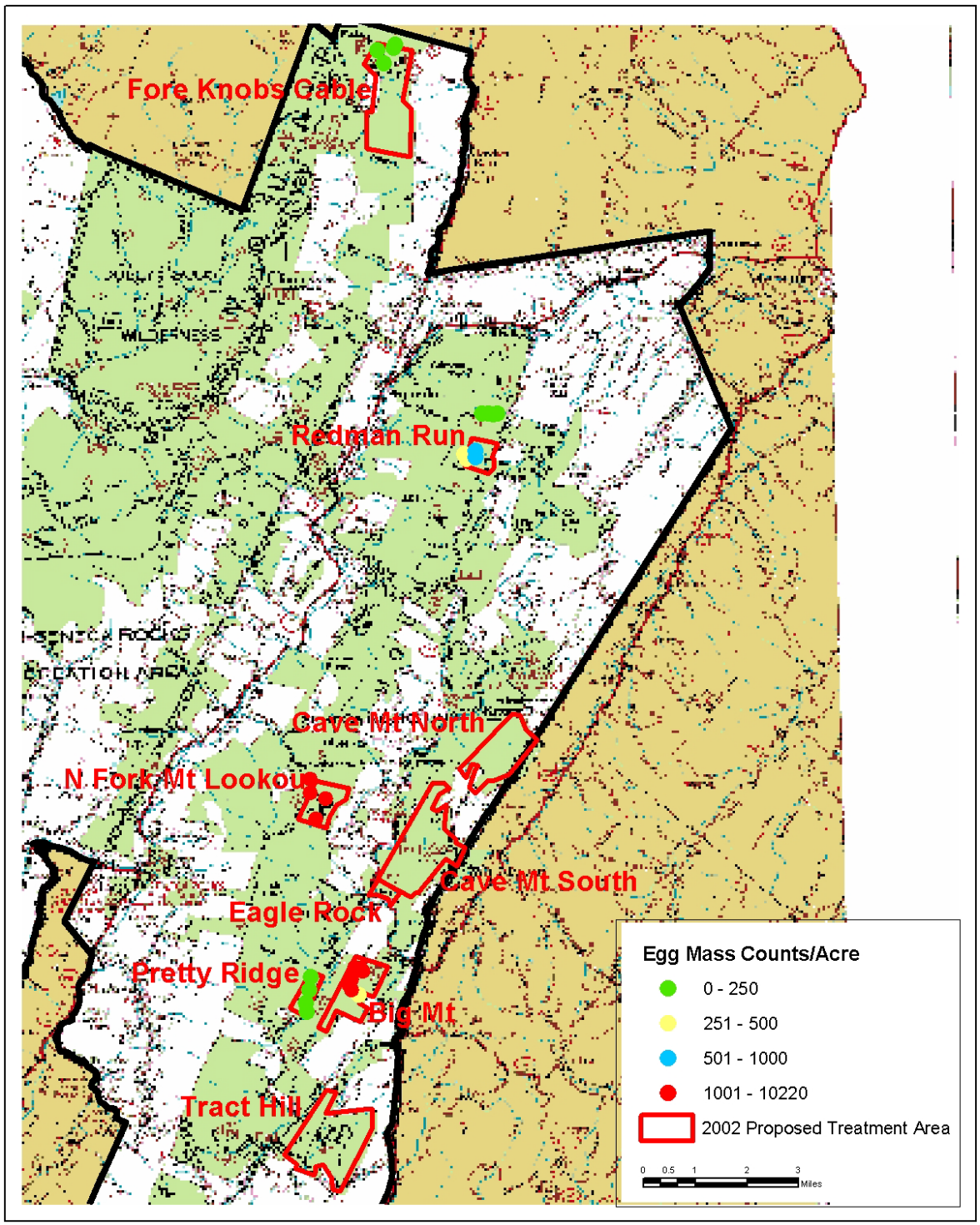

Figure 2. Monongahela National Forest 2002 proposed treatment area and 2003 egg mass counts-Fore Knobs Cable.

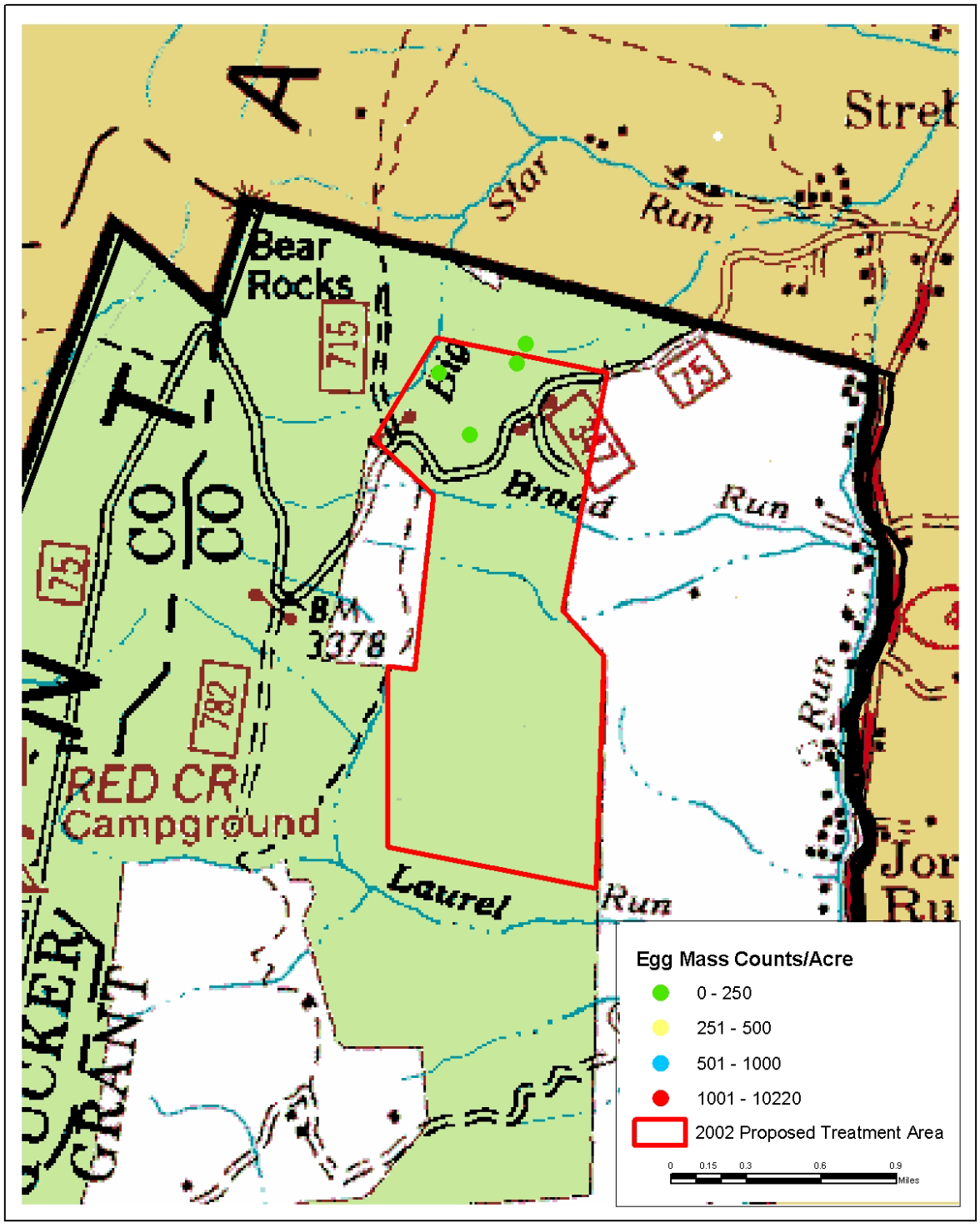

Figure 3. Monongahela National Forest 2002 proposed treatment area and 2003 egg mass counts-Redman Run.

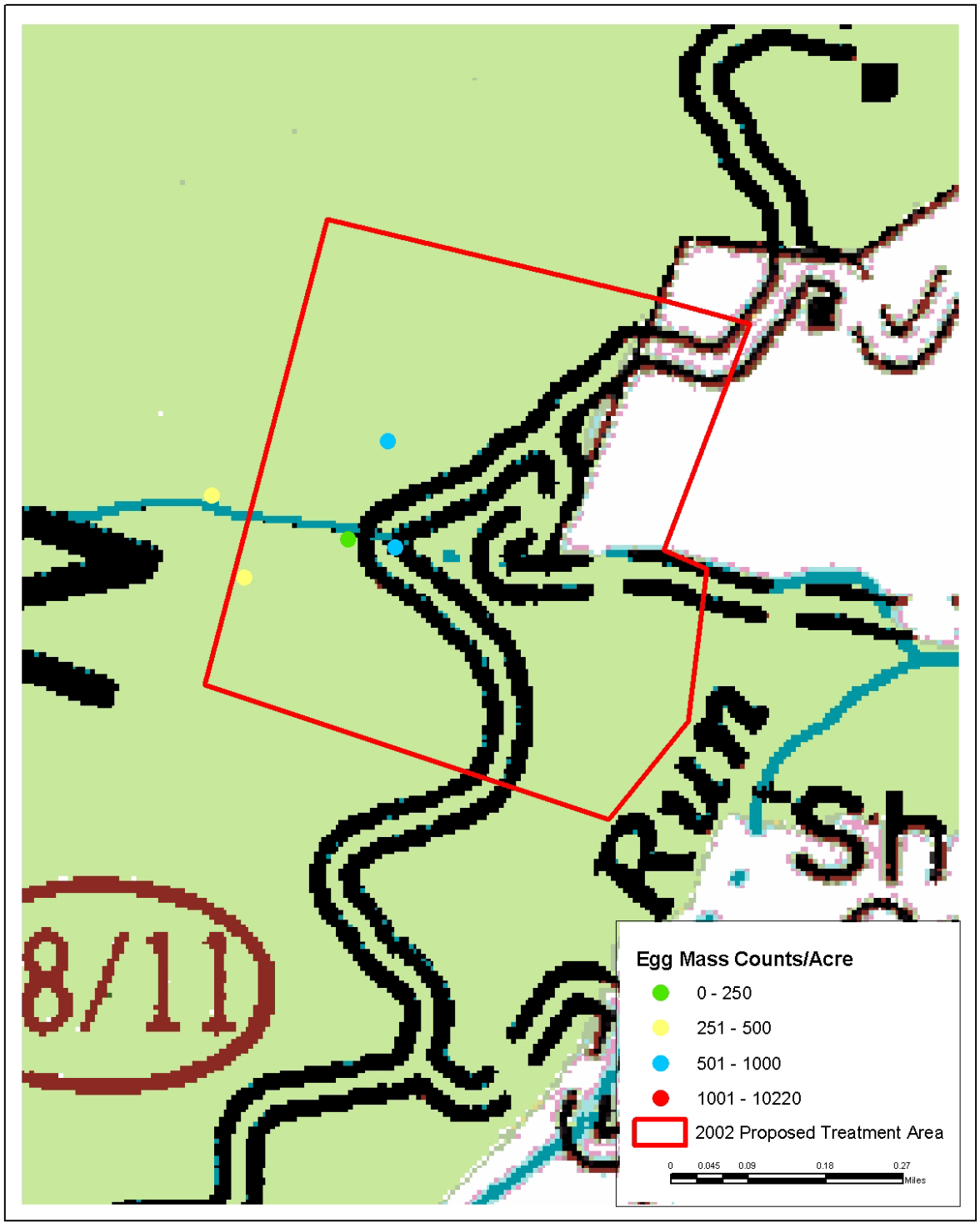

Figure 4. Monongahela National Forest 2002 proposed treatment area and 2003 egg mass counts-North Fork Lookout.

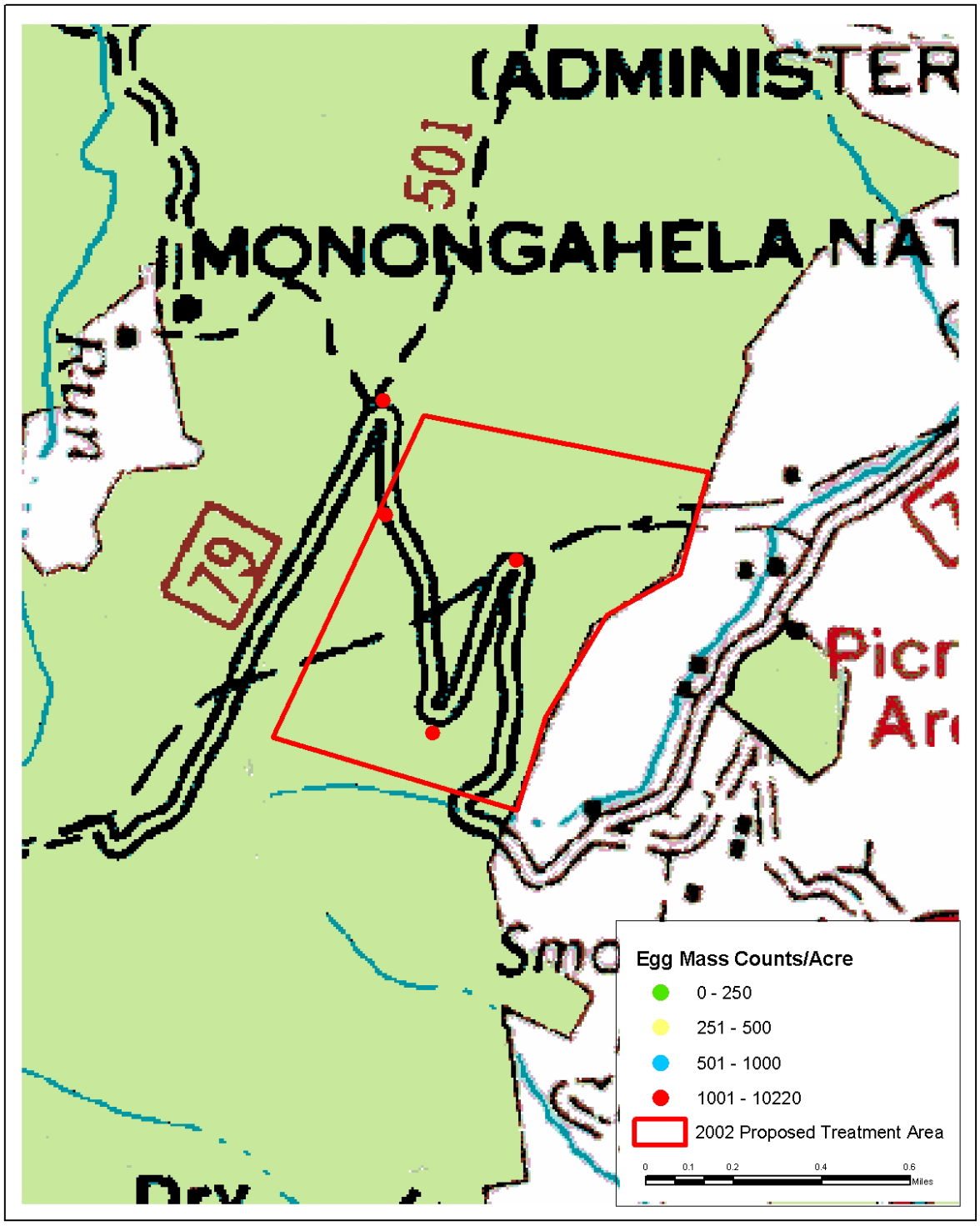

Figure 5. Monongahela National Forest 2002 proposed treatment area and 2003 egg mass counts-Forest Trail 502.

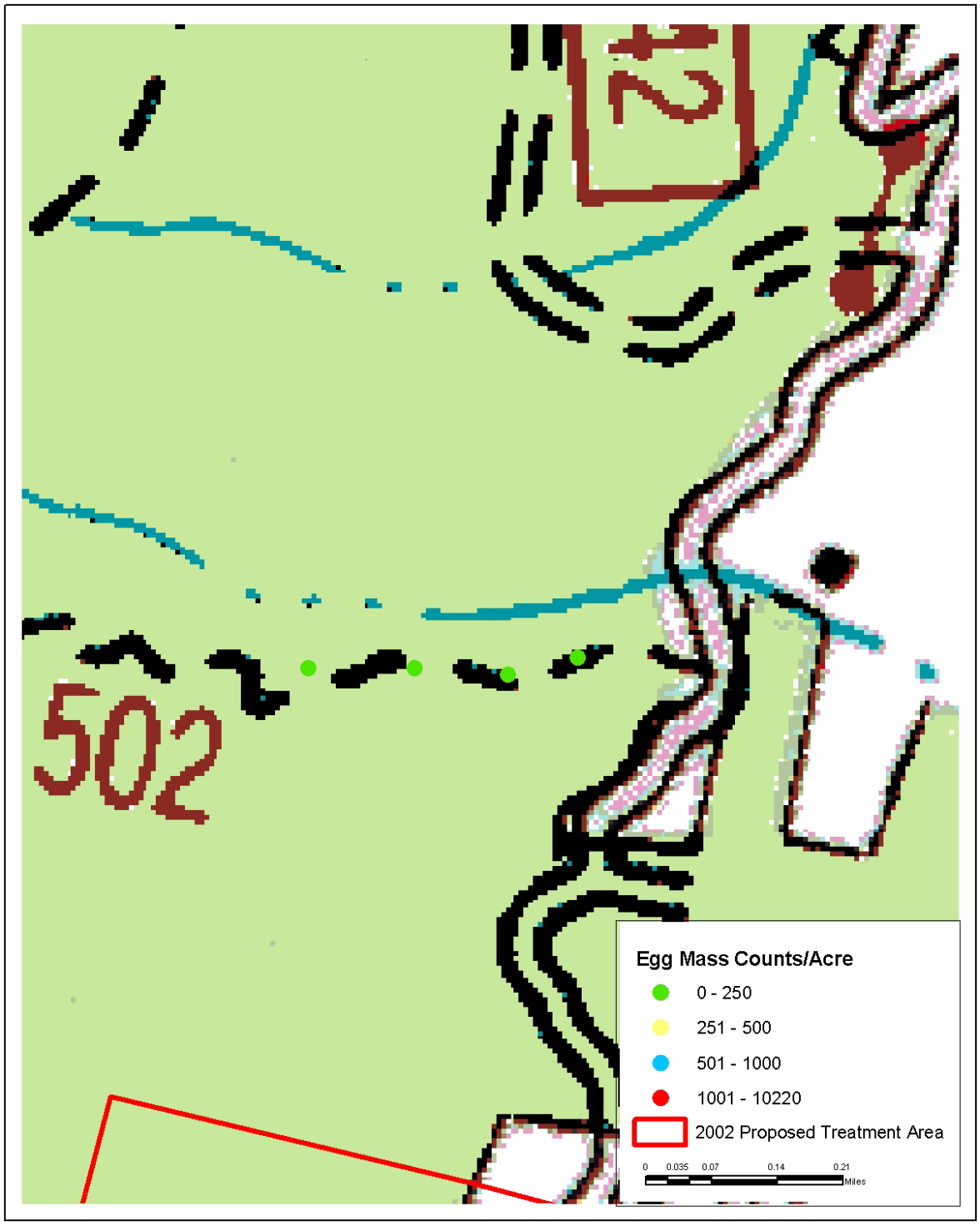

Figure 6. Monongahela National Forest 2002 proposed treatment area and 2003 egg mass counts- Pretty Ridge.

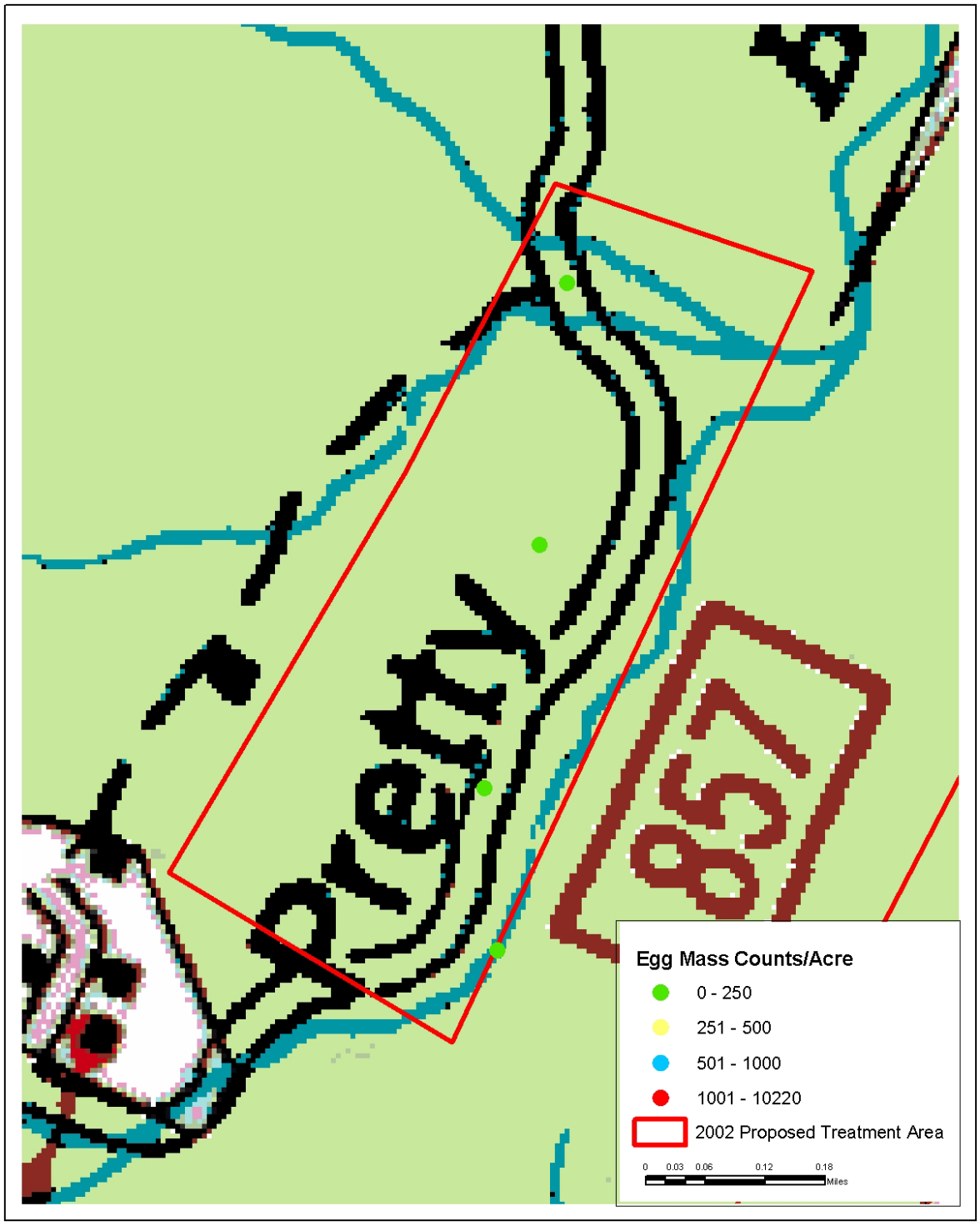

Figure 7. Monongahela National Forest 2002 proposed treatment area and 2003 egg mass counts-Big Mountain.

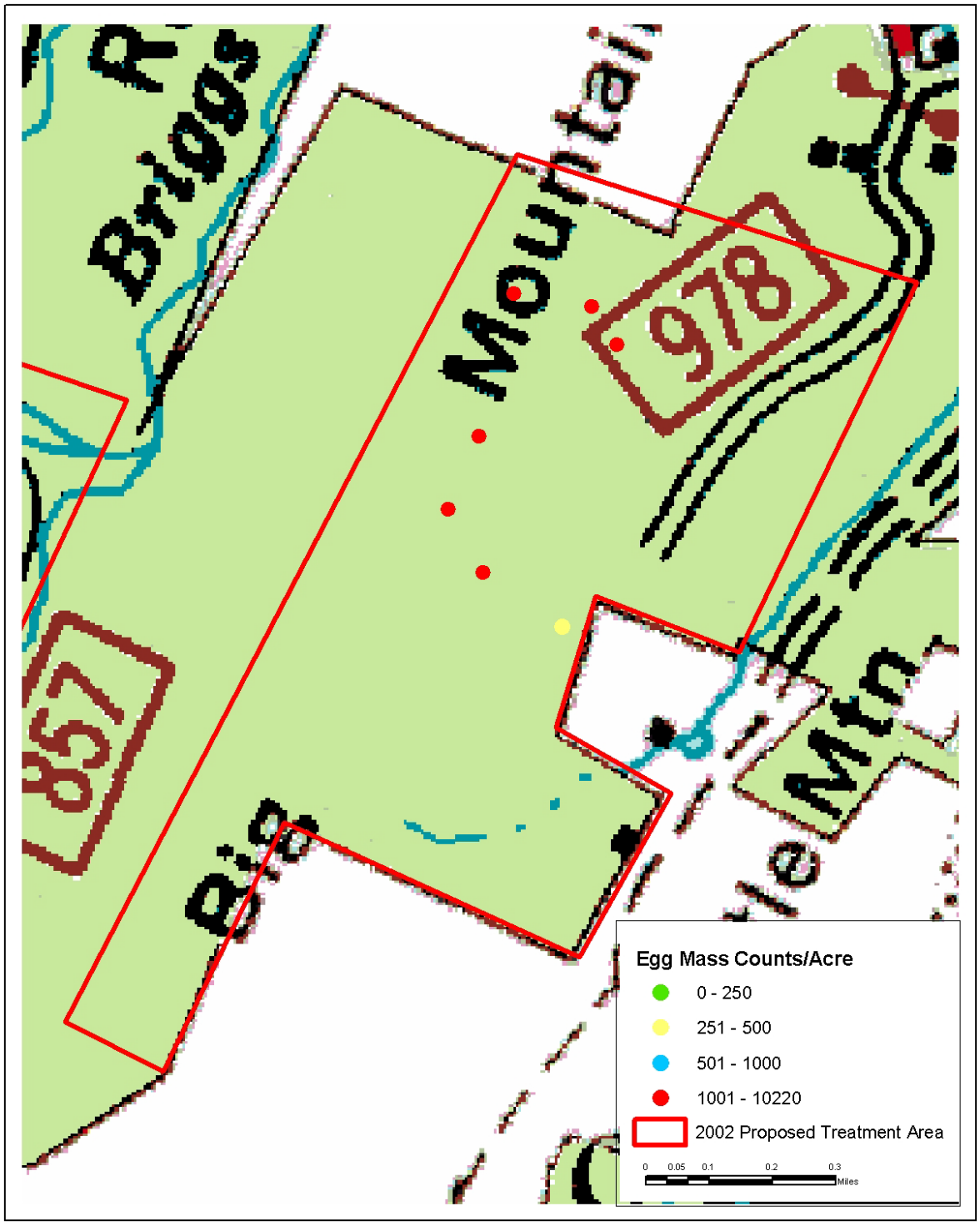

Figure 8. Monongahela National Forest 2002 proposed treatment area, 2001 treatment area, 2002 defoliated area, proposed 2003 treatment area and 2003 egg mass counts- Lake Sherwood.